VMAP
Vegetative Management Alternatives Program

A Guide to Opportunities

Regeneration Strategies as a Proactive Approach to Vegetation Management

Anne Hayes*

Index

Introduction 1
Planning for Regeneration 1
Forecasting Tools 1
Site Conditions 2
Artificial Regeneration 2
Planting 2
Bareroot Stock 2
Container Stock 3
Stock Selection and Competition 3
Direct Seeding 3
Broadcast Seeding 3
Precision Seeding 3
Natural Regeneration 5
Natural Seeding 5
Vegetative Reproduction 5
Advance Growth 6
Summary 7
Appendix 7
Literature Cited 8

Affiliation

* Biotrest Technologies Inc.
Sault Ste. Marie, Ontario
P6A 2X6

Introduction

Vegetative competition is one of the most critical determinants of the success of any forest regeneration project. Many alternatives exist for managing competing vegetation. Herbicides, manual and mechanical cutting, and animal grazing are just a few of the available tools. This technical note focuses on regeneration strategies that can be used as proactive approaches to forest vegetation management.

Broad categories of regeneration methods are artificial and natural. Sometimes the most effective strategy uses a combination of both. With proper planning, regeneration strategies can minimize the effects of competing vegetation while maintaining desired forest ecosystems and achieving management objectives.

Planning for Regeneration

Whether an area is being artificially or naturally regenerated, proper planning is required for success. Planning includes gathering pertinent information about the site being regenerated, reviewing possible regeneration methods, and understanding the management objectives for the area. Factors that should be considered prior to regenerating an area include (OMNR 1997):

- site history
- dominant species in the area
- soil type and moisture regimes
- type and prevalence of competing vegetation
- crop and competitive species reproduction strategies
- site type
- site accessibility
- site conditions for establishment and growth
- nursery stock and/or seed availability
- management objectives
- amount and distribution of advance growth, and
- possible species interactions.

Forecasting Tools

Many decision tools are available to help with the process of planning for regeneration. For example, in its *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario* (OMNR 1997), the Ontario Ministry of Natural Resources (OMNR) provides a series of autecology tables that contain information on growth habit, reproductive characteristics, and response to disturbance for selected species of trees, shrubs, and herbs of the boreal forest. Similar information is provided for Great Lakes-St. Lawrence (GLSL) species in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* (OMNR 1998a). The information in the autecology tables can be used to

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evaluate some of the key considerations for silvicultural treatment stages (e.g. tending, harvesting), including regeneration.

Ecological and management interpretations for boreal forest ecosites are also provided (OMNR 1997). Ecological interpretations presented for each ecosite include, for example, information on advance growth, probability and density of natural ingress (i.e. the establishment of natural regeneration in an open area), site structure and composition, and site productivity. Management interpretations for each ecosite include, for example, management opportunities and recommendations for harvest methods, logging methods, renewal treatments, and tending treatments. The information provided in these interpretations is valuable for planning each silvicultural treatment, and evaluating how each treatment affects other treatments. It can help to evaluate, for example, how a particular harvesting method will affect regeneration on a site, or how harvest methods and/or site preparation techniques can be modified to reduce the predicted impact of vegetative competition. Similar information is provided for ecosites that contain GLSL species (OMNR 1998a).

A list of additional tools that may be useful in planning for regeneration is also supplied by OMNR (1997). Tools listed include keys, guides, and manuals that cover topics such as cone scattering, site productivity, and predicting advance growth. Using these types of tools as part of a regeneration strategy can help in the selection of the most appropriate regeneration method and species for renewal, and increase the likelihood of successful regeneration.

Site Conditions

Understanding the conditions of the site being regenerated is essential for identifying the most appropriate regeneration method and increasing the likelihood of crop trees outcompeting non-crop vegetation. For example, natural regeneration of GLSL conifers is a viable option when the site to be regenerated has a low abundance of competitive species but sufficient water, light, and nutrients for crop seedlings to establish and grow. These conditions are likely to occur on shallow soils that have low nutrient levels and limited moisture retention. Examples of sites that may be well suited to artificial regeneration include (OMNR 1998a):

- sites where there are no crop tree seed sources (e.g. clearcut sites)
- sites where there is a low probability of natural regeneration (e.g. good seed bed availability and receptivity coincides with inadequate seed crop)
- sites where it is not feasible (e.g. inaccessible sites) to create site conditions that would favour natural regeneration, and
- sites where competition is high.

Artificial regeneration methods can also be used to compliment natural regeneration. A combination of artificial and natural regeneration methods is sometimes used to regenerate black spruce and jack pine stands (OMNR 1997).

Artificial Regeneration

The most common types of artificial regeneration are planting and seeding. Planting is done with bareroot seedlings, containers, or, for some species of poplar, cuttings. Seeding is done by aircraft, machine, or hand. Historically, more emphasis was placed on bareroot stock for regeneration in Ontario, but since the 1980s, emphasis has changed to container stock. Due to the rising costs of planting, greater emphasis is being placed on direct seeding (Sarker *et al.* 1995) and natural regeneration for forest renewal.

Planting

Although planting either bareroot stock or container stock is a costly method of regeneration, sometimes the biological and/or physical characteristics of sites, i.e. productive, competitive, or degraded, make planting the most suitable regeneration method. For example, planting is the most dependable method for regenerating black or white spruce in deep mineral soils (Arnup *et al.* 1988). Other times, the characteristics of the crop species make planting the most reliable regeneration method. For example, red pine seed production is extremely variable and small red pine seedlings are highly susceptible to competition from non-crop species. Therefore, planting is the preferred method of regenerating red pine (Chapeskie *et al.* 1989). The reliability advantage of planting has to be weighed against the economics of alternative methods of renewal.

Bareroot Stock

Bareroot seedlings and transplants are raised in nursery beds (Stiell 1984) and are planted with their roots bare of soil (NRC 1995). The length of time plants remain in the nursery varies from two to five growing seasons after germination. The simplest cases involve growing the seedlings for two to three years and then field planting. In other situations, seedlings are transplanted after about two years, and grown at lower densities for an additional one to two years in the nursery before being planted in the field.

Transplanting is used to reduce density, increase uniformity in seedling characteristics, create a dense and fibrous root system, and grow large and robust stock that is able to successfully compete with other vegetation. Currently, most bareroot stock used in Ontario is transplant stock. Although field performance varies with seedling physiology, tree species, soil type, climate, and the type and amount of competing vegetation, generally transplants perform better than seedlings (Mullin and Howard 1973,

Mullin 1980, Racey *et al.* 1989) and are better able to compete. Outplanting success is also highly dependent upon proper handling of seedlings and proper planting practices (Paterson 1993).

Seedling stock is less expensive than transplanting. Therefore, one regeneration strategy is to use transplant stock in areas of high vegetative competition. Although more expensive to produce than seedling stock, transplant stock is more robust and establishes more successfully than seedlings. Conversely, the more economical seedling stock is appropriate for areas with low or moderate competition.

Container Stock

Container planting in Ontario began in the early 1950s (Walters 1961). A containerized seedling is grown individually in a container rather than in a nursery bed. Containerized seedlings are planted with their roots still in the growing medium in which they developed. The result is easily transported and planted seedlings that are sufficiently well developed for planting within months rather than years.

Currently, more than 90 percent of the stock that is planted in Ontario is container stock. Although it is more economical to produce than bareroot stock, there are disadvantages. Most of the limitations stem from their diminutive size and their reduced ability to compete with other vegetation (Scarratt 1974). Chapeskie *et al.* (1989), for example, recommend that white pine container stock be used to regenerate sites where re-invasion by competing vegetation is only expected to be moderate, and that transplanted seedlings be used on sites where the potential for re-invasion by competing vegetation is high. However, with improved tending practices, the survival advantage of bareroot stock over container stock in the presence of competing vegetation has decreased.

Stock Selection and Competition

Some of the negative effects of competition can be countered by the choice of stock used for planting. Selection of the optimum stock requires knowledge of the silvics of the crop and competing vegetation species and the planting site conditions. Johnson *et al.* (1996) summarize the stock types that were available in Ontario in 1996, and provide some guidelines for selecting appropriate stock. For example, smaller stock types are available for less competitive sites while larger stock types are available for more productive sites. Artificial regeneration procedures and practices are constantly evolving and stock type availability changes rapidly making specific recommendations difficult. Information on the most current stock is available from local tree nurseries and greenhouse growers.

In addition to selecting appropriate stock, other tactics that can reduce the negative impacts of vegetative competition on planted crop trees include:

- planting as soon as possible following burning or other site preparation techniques (Ball and Kolabinski 1986)
- planting trees that have high root growth capacities (Burdett *et al.* 1983), and
- using extended greenhouse culture to promote early height growth after planting so crop trees are not overtopped by competing vegetation (Colombo 1986).

Direct Seeding

Direct seeding is the application of seeds to a site by aircraft, machine, or hand. Direct seeding is a low cost regeneration strategy that can be highly effective when site conditions are favourable. Seeding is especially effective on areas with little competition (OMNR 1997). Although it is most often used to regenerate jack pine, direct seeding is occasionally used as a supplementary silvicultural technique for tolerant hardwoods when seed crops fail, natural regeneration is inadequate, or the amount of available planting stock is insufficient (OMNR 1998b). Direct seeding can be particularly effective when used with other regeneration strategies, such as protection of advance growth, which allows for ingress. Direct seeding methods include broadcast and precision seeding.

Broadcast Seeding

Broadcast seeding is the even scattering of seeds, by air or from the ground, across a site (NRC 1995). Aerial seeding can be used to regenerate large areas that would be expensive to plant, as well as areas inaccessible for the delivery of planting stock (Arnup *et al.* 1988). In the boreal forest, broadcast seeding is effective and used extensively to regenerate jack pine. When broadcast seeding is used, ingress levels should be considered when determining seeding rates (OMNR 1997).

Precision Seeding

Precision seeding is the manual or mechanical sowing of seeds and is achieved by spot seeding, with or without shelters, or by row seeding (OMNR 1997). Precision seeding and site preparation can be done simultaneously, which allows for seeds to be placed directly on scarified seedbeds. Jack pine regenerates easily from seed, and thus precision seeding is a cost effective regeneration method (Bryson and Van Damme 1994, Bulley and Bowling 1995). With respect to vegetation management, precision seeding has an advantage over aerial seeding. When precision seeding is done at the time of site preparation, resulting seedlings have a one-year advantage over those that are seeded aerially, because aerial seeding usually occurs in the winter following site preparation. That one-year advantage allows precision seeded seedlings to compete better with non-crop species on the site (Corbett 1992).

Table 1 outlines the advantages and limitations of various artificial regeneration methods.

Table 1. Advantages and limitations of various artificial regeneration methods.

Method	Advantages	Limitations
Planting	↑ greatest control over stand density, spacing and structure (Morgenstern 1975) ↑ effective for competitive sites (OMNR 1997) ↑ decreases rotation period (Morgenstern 1975) ↑ can increase proportion of best-growing trees through selection and breeding (Morgenstern 1975)	↓ expensive (OMNR 1997) ↓ labour intensive (Arnup *et al.* 1988)
Bareroot	↑ generally outperform containerized seedlings, particularly initially, in field trials (Scarratt 1974) ↑ greater tolerance of competing vegetation (Johnson *et al.* 1996)	↓ initial costs to grow are higher than those for container stock (Johnson *et al.* 1996) ↓ labour intensive to produce (McClain 1978) ↓ more difficult to plant than container stock (Ball and Kolabinski 1986) ↓ susceptible to root deformities if improperly planted
Container	↑ longer planting season (Cleary *et al.* 1978) ↑ reduced transplant shock (Cleary *et al.* 1978) ↑ easier to plant than bareroot (Ball and Kolabinski 1986) ↑ more economical than bareroot (Johnson *et al.* 1996)	↓ seedlings are generally smaller than bareroot and more susceptible to overtopping by competing vegetation (Cleary *et al.* 1978) ↓ susceptible to root deformities (Nichols and Alm 1983, Nelson 1989) ↓ susceptible to frost heaving (Cleary *et al.* 1978) ↓ outplanted seedlings may be subject to moisture stress due to poor contact between roots and soil (Cleary *et al.* 1978)
Direct seeding	↑ window of opportunity for seeding is wider than for planting (OMNR 1997) ↑ requires fewer storage and transportation facilities than planting (OMNR 1997)	↓ ineffective on highly productive sites where competing vegetation prevents crop trees from successfully germinating (Dominy and Wood 1986) and establishing ↓ higher seed to seedling ratio ↓ conditions must be suitable for germination as well as establishment and growth
Broadcast seeding	↑ efficient way to regenerate large areas that would be expensive to plant (Arnup *et al.* 1988) ↑ can be used in inaccessible areas (Arnup *et al.* 1988)	↓ inefficient use of limited volumes of high-value seeds (Corbett 1992, Sidders 1993) ↓ seed can be costly and difficult to collect (Corbett 1992, Sidders 1993) ↓ difficult to achieve desired spacing (Corbett 1992, Sidders 1993)
Precision seeding	↑ fewer seeds required for precision seeding than aerial seeding (Corbett 1992) ↑ easier to control spacing (Corbett 1992) ↑ use of genetically improved seed is more feasible (Bulley and Bowling 1995)	↓ ineffective on highly productive sites where competing vegetation prevents crop trees from successfully germinating (Dominy and Wood 1986) and establishing ↓ can be expensive (more expensive than aerial seeding but less expensive than planting)

Natural Regeneration

Natural regeneration is the renewal of desired tree species by seed, vegetative reproduction, or advance growth. Prior to the early 1950s, natural regeneration was the primary method used to regenerate stands in Ontario. Recently, natural regeneration has been reconsidered due to the increasing financial constraints related to stand establishment (Bowling *et al.* 1997).

Several factors affect whether or not a site will naturally regenerate. The type of disturbance that has occurred at the site, the site conditions, the method by which the crop species is able to reproduce, the species itself and its ability to compete with non-crop vegetation, the amount of advance growth on the site and the potential for ingress all contribute to the success or failure of natural regeneration.

Natural Seeding

Natural seeding occurs when seeds are dispersed from standing trees to disturbed areas by wind, birds, gravity, etc. (NRC 1995). Many factors influence the ability of a species to reproduce successfully from seed. Seed availability is a key component and can be a major limiting factor of natural regeneration. For success, good seed years must coincide with seed bed availability and receptivity. Seed production varies annually, but for a site to be naturally regenerated, enough quality seed has to be available following a site disturbance to outcompete undesirable species that may be prolific seeders (Weetman and Vyse 1990, Bell 1991). Some species are able to reproduce from seeds already present in the organic layer and upper mineral soil (Bell 1991); most of these are competitors.

Seed size also affects whether or not a site will naturally regenerate. Some species have large seeds that are not likely to spread far from the parent plant. White pine seeds, for example, are not likely to disperse more than six metres (Weetman and Vyse 1990). Large seeds are also more likely to be eaten by predators. The advantage of large seeds, however, is that they provide stored energy to the germinant, which may allow them to outcompete non-crop vegetation for a few years.

Vegetative Reproduction

Methods of vegetative reproduction include:

- **Suckering:** Suckering occurs when an underground stem or root produces a branch or shoot that becomes an individual plant. Balsam poplar, trembling aspen, large-tooth aspen and American beech commonly reproduce via suckering.
- **Sprouting:** Sprouting occurs when a dormant bud at the base of a tree or on an exposed root produces a shoot. Hardwoods in general commonly reproduce via sprouting.
- **Layering:** Layering occurs when a branch becomes imbedded in an appropriate rooting medium and grows roots. Layering is characteristic of black spruce (Stanek 1961) and, under favourable conditions, layerings will appear and develop similarly to seedlings.

Species that are able to reproduce vegetatively are not reliant on suitable seedbed conditions (Weetman and Vyse 1990) and, therefore, have a competitive advantage over those that reproduce from seed. However, not all species are capable of reproducing vegetatively. Bell (1991) and Sims *et al.* (1990) provide information on the methods of reproduction for major tree species in Ontario. Table 2 outlines the advantages and limitations of vegetative reproduction compared to natural seeding.

Table 2. Advantages and limitations of natural seeding and vegetative reproduction.

Reproductive Method	Advantages	Limitations
Vegetative	↑ rapid stand establishment (OMNR 1997) ↑ low cost (OMNR 1997)	↓ some species (e.g. jack pine, white pine, and red pine) do not vegetatively reproduce (Sims *et al.* 1990) ↓ repeated vegetative reproduction of some species (e.g. aspen) can reduce the quality of resulting stand ↓ clones can be more susceptible to disease and insects
Natural seeding	↑ maintains local gene pool (Weetman and Vyse 1990) ↑ establishes diverse stands (Weetman and Vyse 1990) ↑ improves seedling root form (Weetman and Vyse 1990)	↓ susceptible to germination failure due to unfavourable climatic (OMNR 1997) and/or site conditions ↓ difficult to control stand composition and structure (OMNR 1997)

Advance Growth

In some silvicultural systems, the primary means of regeneration is from advance growth. Advance growth is the seedlings and saplings that are able to establish naturally from seed or layering, grow, and persist under existing canopies. The seedlings and saplings are usually mid-tolerant to tolerant of shade (OMNR 1997), and may or may not be the same species as the overstory (Weetman and Vyse 1990).

Black spruce is a good example of a species well suited to renewal from advance growth. Planting or seeding of black spruce is generally costly and labour intensive, so natural regeneration from advance growth is an attractive alternative. Black spruce is a particularly good candidate for natural regeneration because of its ability to produce abundant seed and, more importantly, its ability to reproduce via layering (Archibald and Arnup 1993). Most of the black spruce advance growth found in a mature forest will have reproduced via layering (Wickware *et al.* 1990). For regeneration from black spruce advance growth to be a successful strategy, pre-harvest stocking levels of advance black spruce growth should be 80 percent or higher (Groot 1984). Other species that may be present as advance growth in the boreal forest include white spruce, balsam fir, and eastern white cedar (OMNR 1997).

Knowledge of the amount of advance growth present on a site can help to predict the likelihood of that site being renewed successfully by natural regeneration. Even more accurate predictions can be made if the amount of non-crop advance regeneration is also known. The OMNR (1997) provides black spruce and balsam fir advance growth densities (stems/ha) for boreal forest ecosites in Ontario. The OMNR (1998a) also outlines the average percent cover of advance regeneration of crop and non-crop trees in each ecosite that may be managed for GLSL conifers.

In areas with sufficient advance growth, natural regeneration should be considered as a viable and economical alternative to artificial regeneration. The economic advantages of preserving advance growth are realized through (Archibald and Arnup 1993):

- elimination or reduction of site preparation costs
- elimination or reduction of costs related to seed collection, stock production, tree planting, or direct seeding, and
- possible reduction in rotation periods due to initial height and size advantage of advance growth.

Renewal via advance growth also has advantages related to competing vegetation. To be successful, careful logging practices are necessary to protect the advance growth. Careful logging keeps the site from being heavily disturbed, reducing the amount of competing vegetation that can invade the site and the amount of tending that the site will require (Archibald and Arnup 1993). As well, advance growth may be better able to compete with non-crop species for resources because of its initial height advantage over planted or seeded trees.

Table 3 outlines some of the advantages and limitations of natural regeneration.

Table 3. Advantages and limitations of natural regeneration.

Advantages	Limitations
↑ can be more economical than artificial regeneration while still achieving forest renewal objectives (Weetman and Vyse 1990) ↑ maintains local gene pools (Arnup *et al.* 1988) ↑ less labour intensive than other regeneration methods ↑ results in better quality stems compared to planted because of higher initial stem densities (Janas and Brand 1988)	↓ variable seed production can decrease the availability of the desired seed resulting in no regeneration or regeneration of undesirable species (Weetman and Vyse 1990) ↓ existing wild stands can be variable in quality (Morgenstern 1975) ↓ poor spatial distribution can result in seedlings growing in clumps (OMNR 1997) ↓ longer regeneration period can increase rotation age (OMNR 1997) ↓ less predictable than planting (Weetman and Vyse 1990)

Summary

Forest renewal is an important element of forestry in Ontario. Vegetative competition can be a major deterrent to successful regeneration, but with proper planning, regeneration strategies can be developed that will minimize the effect of competing vegetation. Understanding factors such as site conditions, site type, predicted prevalence and type of competing vegetation, predicted rate of ingress, and the management objectives for an area being regenerated is essential for choosing the most appropriate regeneration method(s) for that area.

Renewal projects use artificial and/or natural regeneration methods to achieve management objectives, and there are advantages and limitations to both types of regeneration.

Planting is generally costly and labour intensive, but for some productive, highly competitive sites, it is the most appropriate method of establishing a new stand. Direct seeding is generally not as effective as planting on highly productive sites, but it is often used to regenerate jack pine. Natural regeneration methods are more economical and less labour intensive than other regeneration methods, but they are also less predictable. The ecological and economic advantages and limitations of potential regeneration methods have to be evaluated with respect to the properties of the site being regenerated. Many forecasting tools are available to help develop effective regeneration strategies that will decrease the effect of competing vegetation and increase the likelihood of success for renewal projects.

Appendix

Species Listing

Common Name	Scientific Name
American beech	*Fagus grandifolia* Ehrh.
balsam fir	*Abies balsamea* (L.) Mill
balsam poplar	*Populus balsamifera* L.
large-tooth aspen	*Populus grandidentata* Michx.
black spruce	*Picea mariana* (Mill.) B.S.P.
eastern white cedar	*Thuja occidentalis* L.
jack pine	*Pinus banksiana* Lamb.
red pine	*Pinus resinosa* Ait.
trembling aspen	*Populus tremuloides* Michx.
white pine	*Pinus strobus* L.
white spruce	*Picea glauca* (Moench) A. Voss

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